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SEDIMENTATION IN RECTANGULAR BASINS

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SEDIMENTATION IN RECTANGULAR BASINS

Claes N. H. Fischerström,[1] M. ASCE

SUMMARY

The "overflow rate" determines the highest possible sedimentation efficiency obtainable for a given sediment. In a continuous flow basin the actual efficiency is mostly considerably lower than the top efficiency because of disturbances. In this paper the author points to the dominating importance of good hydraulic properties of a sedimentation basin to avoid disturbances, even if hydraulic and sedimentation efficiency do not necessarily coincide. Means of how to obtain good distribution on a number of sedimentation units, good inlets and outlets and especially desired properties of stability and turbulence in the basins are suggested. Because in high rated basins the sludge increase is rapid, the sludge problem is discussed in relation to the quality of the sludge. Some types of basins for different kind of liquids and sediments are described.

INTRODUCTION

The author was lead to the conclusion that elimination of disturbances was the major problem in sedimentation, by studying several delicate cases of cold water sedimentation of soft humus waters in Scandinavia.

Also the remarkable fact that the overflow-rate theory, presented by Hazen[2] in the year 1904, in the past more than 50 years, has not been well confirmed in actual operation, was an evidence that in basins as designed and built hitherto, disturbances still play too big a role.

Though the studies herein are made chiefly on sedimentation of light, flocculous matter, the general conclusions are valid for all kind of sedimentation.

Theoretical Considerations

Sedimentation is a very complicated process, and there are a number of factors whose influence can not yet be expressed by mathematical equations. To study the process mainly from a hydraulic point of view, it is necessary to make assumptions regarding other factors and consider them as constant under the variation of the factors under study.

In any given basin with a fixed over-flow rate the sedimentation will be influenced by two types of factors, such in which the sediment itself plays an important role and those which are, or can be, independent of the sediment. To the former group belongs:

Settling velocities and type of settling (type and amount of sediment as diameter, net density, masscurve, concentration a s.o. viscosity of the liquid).

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1. Cons. Engr., Vattenbyggnadsbyrån (VBB), Stockholm, Sweden.
2. Hazen, Allen, M. ASCE.: On Sedimentation, Trans. ASCE, Dec. 1904.

Flocculation
Bottom scouring
and to the second group:
Wall effect
Kinetic currents
Density currents
Turbulence

Some of the latter factors cause short-circuiting and dispersion. A very complete discussion of these factors are given in modern hydraulics,[3] and by Camp.[4] This paper will deal primarily with the influence on sedimentation by the latter factors although their relation to the other factors must be considered.

Before making necessary assumptions a study of some typical cases of flow in a channel or rectangular basin is required.

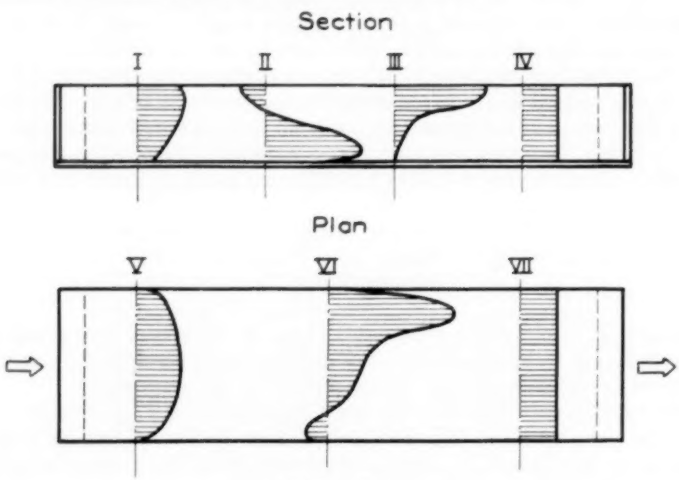

Fig. 1

Fig. 1 shows section and plan of the basin. The section shows the vertical distribution of flow. Type I is "the undisturbed natural flow." Type II is a typical bottom flow with reverse flow at the surface. Type III is a typical surface flow and type IV is "ideal flow." Theoretically these different types do not influence the over-flow rate of the basin if other factors are regarded as unchanged and the distribution over the width is constant per unit of length, because the total flow in each section will be the same independent of the velocity distribution.

Under actual conditions reduced efficiency at top load, or a lower capacity, which is the same, seems to be the result at type II due to earlier scour and increased turbulence, at type IV because of earlier scouring and at type III owing to greater turbulence than at type I. This is valid if the influence of scouring is greater than the influence of turbulence as most observations indicate.

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3. Rouse, Hunter, Prof., Engineering Hydraulics, New York, 1950. Davis, C. V., Handbook of Applied Hydraulics, New York, 1952.
4. Camp, Thomas R., Prof., M. Am. Soc. C. E.: Sedimentation and the Design of Settling Tanks, Transactions, Am. Soc. C. E., Dec. 1945, p. 895.

The plan shows the horizontal distribution. Type V is undisturbed natural flow, type VI a typical lateral flow with or without reverse flow on the opposite side and type VII is ideal flow. An uneven distribution over the width and in the horizontal projection of the water acts as different overflow rates. Only the ideal flow will give the theoretical lowest possible overflow rate. But this is not necessarily giving us the best sedimentation efficiency, as the following example will prove.

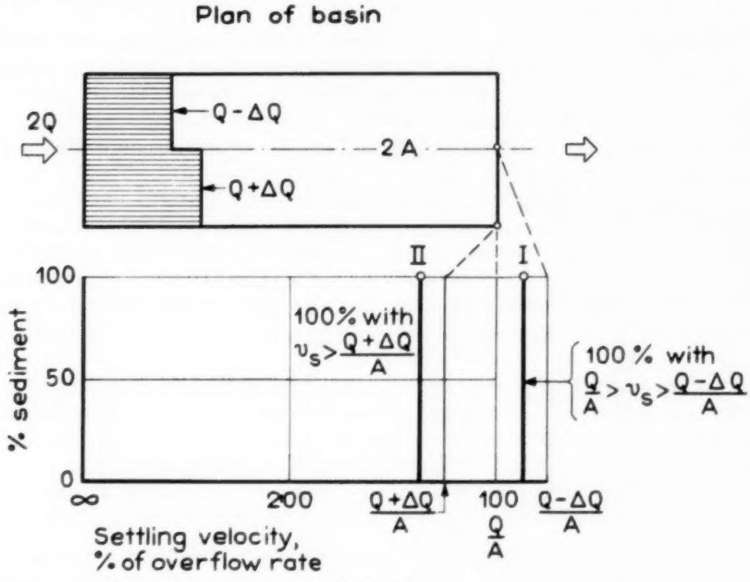

Fig. 2

Assume a sediment analysis as characterized by fig. 2. The sediment contains two grain sizes, one with a settling velocity slightly less and the other slightly higher than the overflow rate. In an ideal basin only the coarser particles will settle. Assume a basin with an uneven water distribution, such that about one-half side has an overflow rate slightly higher than the mean overflow rate but still less than the settling velocity of the coarser particles and the other half side has an overflow rate less than the settling velocity of the finer grains; then all coarse particles and part of the fine particles will settle and the efficiency will be increased.

The above discussion is brought forth only to show that simplified assumptions are not always correct under very special conditions, and hence may be criticized from a scientific point of view. But the designing engineer can not possibly produce a basin with certain specific irregularities occurring e.g. at a certain composition of the sediment. Such a basin will, no doubt, be a bad basin on most other occasions. The conclusion will be to design a basin with controllable flow, and after careful investigation of the type of sediment and other influencing factors, to chose the overflow rate of the basin.

If it is important to avoid disturbances in a basin, the choice between "natural undisturbed flow" and "ideal flow" as an assumption when discussing the possibilities to get an undisturbed flow is still not made. There may be reasons to believe that the former will give the best settling, but an assumption of ideal flow will simplify most calculations. Necessary corrections

when checking a basin's scouring velocity or turbulence are easily made. The author therefore assumes a uniformly distributed "ideal" flow in all cases where special definitions are not made. Other assumptions are free settling and normal composition of the sediment, although it is believed that the conclusions also are generally valid for hindered settling.

Drawn from these assumptions, some different types of settling will be considered.

a) Vertical vs Horizontal Settling

In a vertical ideal flow basin all particles with settling velocities higher than the overflow rate will settle, but no other particles can settle, because the velocity of upward flow is equal to the overflow rate. This basin is not common in practice but is sometimes used as a grit remover as in the BLUNK grit separator.[5] It has the advantage of separating material of a certain size.

In a horizontal ideal flow basin all particles with a settling velocity higher than the overflow rate will settle, together with part of the smaller particles, e.g. 50% of those with a settling velocity equal to 0,5 times the overflow rate.

Thus, the efficiency of sedimentation of discrete particles with a settling velocity lower than the overflow rate is higher at horizontal flow than at true vertical flow, fig. 3.

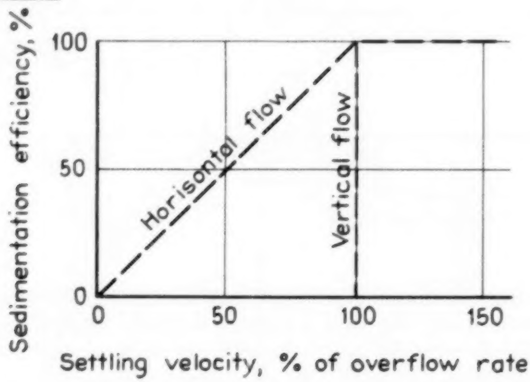

Fig. 3

In basins of mean types with undisturbed flow e.g. the rectangular basin with successive draw-off, or the radial flow basin with central vertical inlet downwards, in which the flow is at the same time vertical and horizontal, the settling will be the same as in a horizontal basin. The successive draw-off does not improve sedimentation. This will easily be understood from fig. 4, showing the rectangular basin.

If the flow is ideal, the water passes in straight paths from the inlet to the surface, where it is removed at the overflow rate. The section of the basin beneath a straight line extending from the lower inlet side to the upper outlet side will not be utilized. In other words, there may be supposed to be a theoretical bottom along this line. In the active part of the basin there will be a constant upward flow equal to the flow divided by the surface area, that is the overflow rate, and the horizontal velocity will be constant. A discrete

5. Bach, H.: Die Abwasserreinigung, Berlin 1934, p. 69.

Section

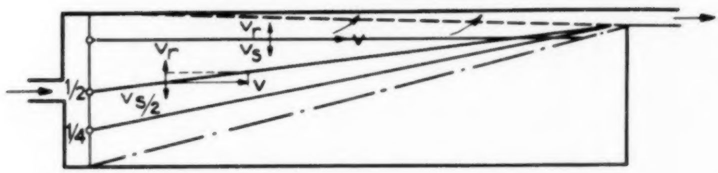

Fig. 4

particle with the settling velocity equal to the overflow rate has equal downward and upward velocities, and the vector sum of its velocities is the horizontal velocity of the liquid. The particle will move horizontally in a straight line, and will hit the end at unchanged depth. All particles whose velocities exceed the overflow rate will settle. Lighter particles will settle in the same manner as in an ideal horizontal basin. For instance, a particle at the inlet center with a settling velocity equal to 0,5 times the overflow rate will hit the end at the upper outlet side, and 50 per cent of these particles will be removed.

Most existing basins of these types are very unstable because of the retarding velocity of flow and the outlets are not perfect, but cause currents. The assumptions of undisturbed flow are hence not fulfilled. All basins with skimmers which the author has tested have given better result when the skimmers were removed. It is, however, possible to improve the design of such basins, as described in the next section.

b) Horizontal Basin with Stories Operated in Parallel

According to the Hazen theory, a basin with a greater surface area is more efficient than a basin with a smaller area, even if the volume is the same. Hazen suggested the use of trays in basins in order to increase the settling surface area. If the stories are operated in parallel, the flow will be reduced on each tray. Suppose a basin has a horizontal area A, 2 trays (3 stories), and a flow Q. Then, the overflow rate is

$$\frac{Q/3}{A} = \frac{Q}{3A}$$

Fig. 5 shows the increased efficiency properties. As can be seen from this diagram, the improvement in sedimentation can be considerable, especially on the first and the second tray. This does not imply that little would be gained by increasing the number of trays. On the contrary, the last tray may be vital, and can decide whether sedimentation can take place or not. If sedimentation is regarded as an overflow-rate problem only, the value of additional trays depends on the mass-curve of the sediment or, which is the same, whether the basin is heavily loaded or not.

c) Horizontal Basins with Stories Operated in Series

In a horizontal basin with several stories operated in series, the whole flow Q passes through each story. For example, in a basin with a horizontal surface area A and 2 trays (3 stories), the total bottom area is 3A. The overflow rate is very often taken to be $\frac{Q}{3A}$, but this is not correct.

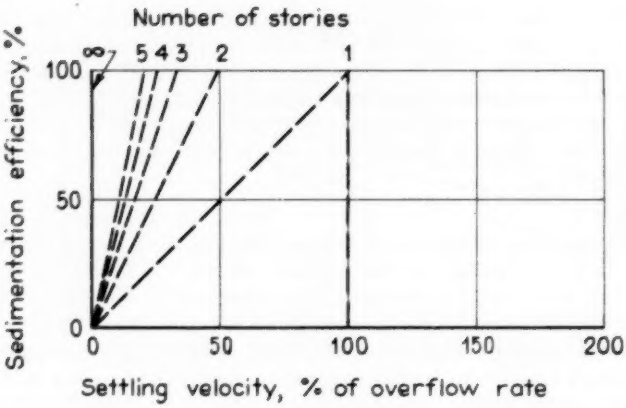

Fig. 5

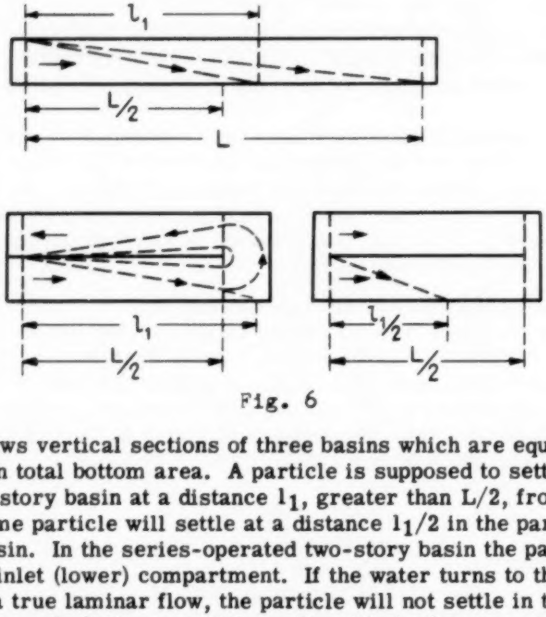

Fig. 6

Fig. 6 shows vertical sections of three basins which are equal in effective volume and in total bottom area. A particle is supposed to settle in the straight one-story basin at a distance l_1, greater than L/2, from the inlet end. The same particle will settle at a distance $l_1/2$ in the parallel-operated two-story basin. In the series-operated two-story basin the particle will not settle in the inlet (lower) compartment. If the water turns to the upper compartment in a true laminar flow, the particle will not settle in the upper compartment either. In fact, no particles will settle in the upper compartment. In practice there will be a more or less complete mixing in the space or channel between the stories of a series-operated basin. Fig. 7 shows curves computed on the assumption that the mixing is complete.

d) Series vs Parallel Operation

The fine sloping lines (2) and (3) in Fig. 7 show that multiple storey-basins operated in parallel, or in series, can differ greatly in sedimentation efficiency. This may be of importance, especially if the mass-curve of settling particles indicates a large amount of particles with low settling velocities.

e) General Remarks

The above takes no respect to flocculation or agglomeration of the sediment, which can be accelerated in basins with mixing and turbulence.

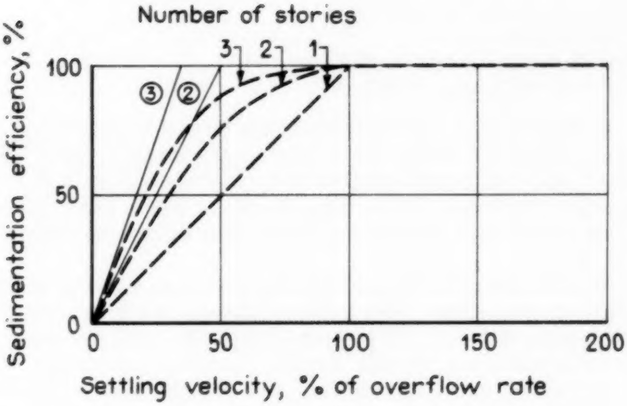

Fig. 7

In most cases the conditioning of the sediment can best take place outside the sedimentation basin. This is especially true in chemical treatment. The chemical conditioning can be improved by efficient instant mixing and by avoiding short circuiting in the stirring basin. But untreated waters may also be conditioned before sedimentation, as is shown by the investigations regarding preaeration of sewage. It seems to be doubtful to mix two such different processes as conditioning and sedimentation.

Agglomeration may take part even in a good sedimentation basin. The experience of the author is that disturbances favouring agglomeration are of minor importance than factors governing sedimentation, as is shown by examples given in the following.

Necessary Conditions for Causing Flow in a Basin Tending Towards the Ideal Flow

It is not, and never will be, possible to produce ideal flow in a basin. But even if true ideal flow cannot be obtained, it is evident from the foregoing that it is of primary importance to produce a flow that is as nearly ideal, or at least as undisturbed as possible, and it is necessary to learn how to do this. Thereafter it will be much easier to study the influence of other factors.

Settling is influenced by various hydraulic disturbances. The main disturbances are turbulence, density currents and kinetic currents. Much has been written about these disturbances, and we shall confine ourselves to those factors which are important for understanding the principles of design stated further on.

a) Turbulence

Turbulence in a basin is caused by an excessively high water velocity. But turbulence is not only dependent upon the water velocity. In a basin with columns, crossbeams, rough walls, etc., turbulence occurs at a lower velocity than in a smooth channel. The turbulence is also influenced by the shape of the channel. The type of flow is generally characterized by the Reynolds number

$$\underline{R} = \frac{V \cdot R}{\nu}$$

where

V = velocity of water, ft./sec.
R = hydraulic radius, ft.
ν = kinetic viscosity of water, ft.^{2}/sec., =
= 1.93×10^{-5} ft.^{2}/sec. C 32^oF

It has been found from investigations that a Reynolds number of 500 (0^oC or 32^oF), or less, indicates laminar flow in open channels, while a Reynolds number above 2,000 indicates turbulent flow. Between these values, the flow may be laminar or turbulent. This depends on the shape and the condition of the channel, on whether the initial flow is laminar or not, and on other circumstances.

Most basins are now operated at Reynolds numbers varying from about 1,000 to 25,000 or even more. The higher numbers are generally to be found in basins for sewage disposal. It is very difficult to design economical basins with low Reynolds numbers. A high Reynolds number indicates a stronger turbulence, which may cause bad settling, and even erosion and traction of sediment.[6] So far, however, there is very little evidence as to the limit at which an obvious decrease in settling efficiency under different circumstances is due to a high Reynolds number alone.

Generally speaking, a lower $\underline{R}$ must be better than a higher one and this is more important when the settling properties of the sediment are bad. A value of about 500 or below would be most desirable for sedimentation of very light flocculent matter. The author is of the opinion that there is not much difference in settling efficiency where the Reynolds numbers in the turbulent zone are not too varied, but there might be a noticeable improvement as soon as the Reynolds number is in the laminar zone.

b) Density Currents

A liquid containing much suspended matter is heavier per unit volume than the same liquid after settling, when it contains little or no suspended matter. The specific gravity of a liquid increases as the temperature decreases, as the salt or the suspended solids content becomes higher, etc.

When the cross-section of the basin is large and the water velocity is low, an incoming liquid having a higher specific gravity than the liquid in the basin will sink to the bottom, and will then flow on the bottom to the outlet weir, while the surface water will turn backwards. The bottom velocity may be so high that settling is impossible or will not occur until the liquid has passed through the greater part of the basin. A lighter liquid will flow near the surface.

The above phenomena are well known. It is also known that a higher medium velocity can often obviate or at least reduce these difficulties. Many cases are reported, when better results were obtained by cutting out a number of basins. Some long basins (tunnels) have been found to be extremely good.[7]

Stability of flow is the ability to withstand disturbing factors. It is not only dependent on the water velocity. The necessary conditions for stable flow under different circumstances are stated in hydraulics. For the following discussion of flow in a settling basin, it may be sufficient to refer to the Froude number

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6. Dobbins, William E.: Effect of Turbulence on Sedimentation, Trans. A.S.C.E., Vol. 109, 1944.
7. Langlier, W. F.: Shallow Sedimentation Basins, JAWWA, 1930, p. 1485.

$$F = \frac{V^2}{R \cdot g}$$

where

V = velocity, ft./sec.
g = gravity constant, ft./sec.^{2}
R = hydraulic radius, ft.

$\underline{F}$ may also be written

$$\underline{F} = \frac{\frac{mV^2}{2}}{\frac{R}{2} \cdot mg} = \frac{\frac{mV^2}{2}}{\frac{R}{2} \cdot w}$$

where

m = the mass of a certain definite portion of the liquid,
w = the weight of the same portion.

It is to be noted that $\underline{F}$ may be regarded as the ratio of the kinetic energy to the weight of a certain definite portion of the liquid. This ratio should be sufficiently high in order to produce a stable flow. Variable velocity or decreasing velocity reduces the stability of flow, while increasing velocity improves this stability.[8]

The importance of stability has been emphasized so many times that it is unnecessary to stress it again. If the stability or the Froude number is too low, we have the well-known bottom and lateral flows, which are so detrimental to settling efficiency. To prevent these currents, the settling basins are designed for ever-increasing velocities. This results in an ever-increasing Reynolds number and turbulence, if no special arrangements are made.

As yet it is only possible to give but a few examples of desirable values of the Froude number. They are no doubt dependent on the shape of the basin, especially the length to depth ratio. In deep and short basins the force acting upon the incoming water will be greater and the hydraulic resistence smaller than in a shallow, long basin, and higher Froude numbers will be required in the former basin than in the latter one. For settling a soft coagulated water, fairly clear but strong in colour, in not too big sections of a basin (longitudinal divisions about 5 ft. x 5 ft.) values of $\underline{F} > 10^{-5}$ have given good results.

c) Hydraulic Conditions

From the above discussion it seems to be of special interest to the designer of an artificial settling basin to consider the "shape" of the basin from a hydraulic point of view. The first question is then:- is it possible to make a plain basin with quite unobjectionable values of the Reynolds and Froude numbers, say, 500 and 10^{-5} respectively? Is this basin acceptable from a technical and an economic standpoint?

If the desirable values are substituted in the expressions for the Reynolds and Froude numbers, and if the velocity V is eliminated, then the hydraulic radius R of such a basin is found to be

8. Nikuradse, J.: Untersuchungen über die Strömungen des Wassers in konvergenten und divergenten Kanälen. Forschungsarbeiten, 1929.

$$R = \sqrt[3]{\frac{\nu^2 \mathbb{R}^2}{g \cdot \mathbb{F}}} =$$

$$R = 919 \cdot \nu^{2/3}$$

Since the kinetic viscosity is dependent upon the temperature of the fluid, the hydraulic radius for the settling basin requested will vary at different temperatures. For water with a temperature of 0°C (32°F) and 20°C (68°F) the hydraulic radius R is computed to be

$$R_1 = 0.66 \text{ ft.}, \quad 0^\circ C$$
$$R_2 = 0.45 \text{ ft.}, \; 20^\circ C$$

For water purification in cold climates the lower temperature seems to be the important one, while settling of sewage mostly takes place at the higher temperature. As an example we compute the dimensions of a basin at 20°C water temperature which will result in a more extreme shape than at a lower temperature and for a capacity of 4.6 m.g.d. and an overflow rate of 1,200 gallons per sq. ft. per day. The medium velocity will be:-

$$V = \frac{\nu \cdot \mathbb{R}}{R} = \frac{545 \cdot 10^{-5}}{0.45} = 0.012 \text{ ft./sec.}$$

and hence the cross-section area:-

A = sq. ft.

The depth d and the width b of the basin are obtained from the equation

$$R = \frac{A}{P} \text{ or } 0.45 = \frac{599}{b + 2d}$$

and bd = 599
where P = the wetted perimeter.
Hence b_1 = 1300 ft. b_2 = 0.885 ft.
and d_1 = 0.445 ft. d_2 = 656 ft.

At a supposed overflow rate of 1,200 gal./sq.ft./day the requisite horizontal area of the basin is 3880 sq. ft., and the length of the basin is

L_1 = 2.98 L_2 = 4'360 ft.

Consequently, the answer is:- two basins, one extremely short and wide, with a depth of only 5.4 in., the other extremely narrow, deep and long. It is not necessary to discuss why these basins are unpractical to use, especially for settling of sewage.

If we assume the upper limit of R for laminar flow to be 2,000, the following basin data, Fig. 8, will be computed on the same assumption.
These basins are still comparatively extreme in shape. The shallow basin may possibly be developed into a basin that is acceptable from an engineering standpoint. It is of interest to observe that the wide basin is by far the most economic one. The surface of the two basins is the same, 3880 sq. ft., but the depth of the narrow basin is 145 times as great as the depth of the wide basin.

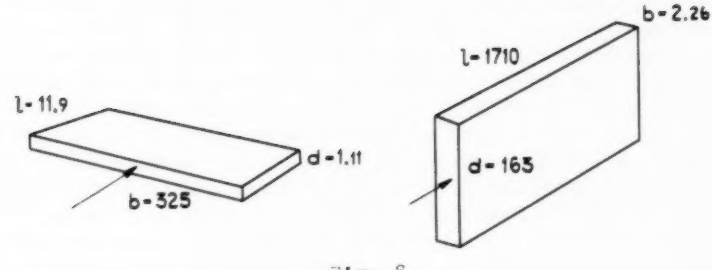

Fig. 8

The above examples show that it is of interest to find other ways to design a basin so as to obtain desirable values of the Reynolds and Froude numbers. Since m and p in the formula for F are given for a certain definite liquid to be settled, F can be increased only by raising the water velocity V or by reducing the hydraulic radius R. An increase in the water velocity will increase the Reynolds number, which is already perhaps far too high in most basins. Therefore, we shall discuss the possibilities of reducing the hydraulic radius. R is expressed by the equation

$$R = \frac{A}{P}$$

where

A = the area of the wetted cross-section
P = the wetted perimeter, and hence

$$\underline{R} = \frac{V \cdot A}{\nu \cdot P} \quad \text{and} \quad \underline{F} = \frac{V^2 \cdot P}{g \cdot A}$$

For a given basin R can be reduced only by increasing the wetted perimeter P. This will not only reduce the Reynolds number, but also increase the Froude number. For instance, this can be done by using longitudinal baffles, which may be horizontal, vertical, or sloping, see Fig. 9 a-c.

Cross sections of basins with longitudinal walls

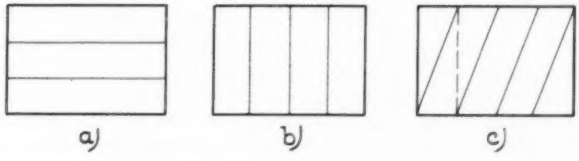

Fig. 9

From Fig. 9 a it is seen that horizontal baffles reduce both the hydraulic radius R and the overflow rate. The same effect will also be produced, though to a lesser degree, by sloping walls, Fig. 9 c. Since horizontal trays reduce both the overflow rate and the Reynolds number, and increase the Froude number, they should be used as widely as possible. "Tray settling tanks"

have been suggested more than 50 years ago, e.g. the multitray circular tank with a revolving scraper mechanism, but the main reason for this suggestion was a reduction in the overflow rate, and perhaps not an improvement in the hydraulic conditions. Camp has shown an extreme design of a rectangular tray settling[9] basin. Such basins are ideally suited for settling discrete particles of inert materials. Experience has shown that similar basins have their limitations when settling very light flocculent matter, because of the uneconomically high water content of the sludge withdrawn, which is due to the very short runs resulting from full-load operation of multiple tray basins. This matter will be discussed in the following. In such cases it may be necessary or preferable to use a basin with not too many trays, and with ample room for the sludge, in order to get as long runs as are needed to obtain a sufficiently thick sludge. In such a basin, according to the above theory use can be made of additional vertical or sloping longitudinal walls, so as to ensure stability and nonturbulence, or at least to reduce turbulence. By using a sufficient number of such walls it is always possible to obtain the desired values of Reynolds and Froude numbers, which are necessary in order to produce reasonably stable, low-turbulent flow of the liquid to be settled.

The upper compartment may be provided with a "wetted roof," or with one additional longitudinal wall and a depth equal to half the depth of the underlying compartments, Fig. 10, in order to obtain the same hydraulic properties as the underlying compartments.

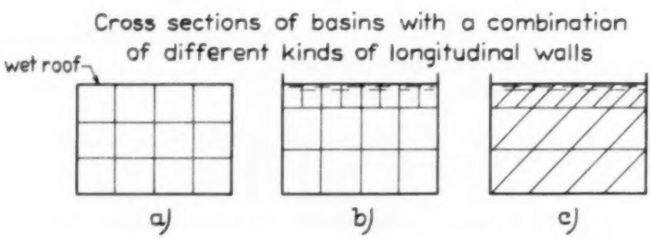

Fig. 10

It is interesting to note that the computation above by means of hydraulic constants will, on the whole, lead to the same shape as computations made by Camp by means of the velocity, which will not scour namely a shallow, wide plain basin or—which is the same—a number of shallow basins arranged in parallel either side by side or on top of each other. The difference is mainly that the scouring velocity condition gives a fairly high Reynolds number and a very short detention time, that is a more extreme basin. As an example we can take Camp's basin No. 8a,[10] which has a Froude number of $3.5 \cdot 10^{-3}$ and a Reynolds number of 3 700 at a recommended scouring velocity of 0.16 ft./s. According to the above theories it is possible to install longitudinal walls in the basin in order to obtain a lower Reynolds number.[11]

None of the methods for computing the settling zone will remedy the sludge problem.

9. Loc. cit. (4), p. 2.
10. Loc. cit. (4), p. 2.
11. Compare also Jenks, Harry N.: Sacramento Sets New Standard in Pre-Treatment, Eng. News Rec., July 6, 1933.

Even if the basin is of a "good" design, it is sometimes difficult to produce satisfactory flow of the water in the basin. This happens when the water to be settled is extremely high in turbidity or in sludge content. Such waters may sink to the bottom of the compartments of the basin even after a perfect distribution in a basin with a fairly high Froude number. It is important in such cases to let the bulk of the sludge settle out, so that the liquid then behaves more ordinarily, and a reliable high efficiency can be reached. This may sometimes be done in the basin by fitting perforated bottom baffles near the inlet end, or if necessary in a specially designed pre-settling basin.

d) Kinetic Currents

The kinetic energy in the water from the inlet pipe must be reduced and "distributed" quite uniformly over the inlet cross-sectional area. This is extremely important in wide basins or in basins divided into a number of longitudinal channels. Of course, the water can also be "proportioned" by drawing off the right amount from each channel or by applying both these principles. When settling alum floc. it is not possible to use high-velocity proportioning, and the problem becomes very difficult. Sometimes the velocity at the inlet end must be kept below 0.17 ft. per sec., and in such cases it seems to be necessary to make elaborate arrangements for the distribution both at the inlet and at the outlet ends. The velocity at the outlet end may be kept higher, perhaps 1 ft. per sec., without disturbing the filter effect.

Large amounts of water are more difficult to distribute than small ones. The water has a tendency to "shoot" through, and may cause stationary regions of flow, with a high velocity forwards in one channel, and standstill in another. It seems to the author that a successive "centre of gravity" distribution is the best way to get a good inlet. The main inlet at the center of the first baffle is divided into four parts at the center of each square of the next baffle, and so on. The last baffle must be provided with uniformly distributed openings. The large openings in the first one or two baffles may consist of a number of smaller pipes, so that there will be no strong tendency to lateral flow. The space between the baffles should be drained every time the basin is cleaned.

When the sediment is putrefactive self cleaning, inlets are necessary, which will require less efficient distribution arrangements.

The outlet should be designed by the same principles as the inlet in the perfect basin. To avoid the influence of bottom currents at low load, it is preferable to raise the outlet openings to the upper part of the outlet wall. The openings should be designed for the highest possible velocity that is acceptable.

The inlet and outlet of every basin must be trimmed after being put into service. This is done e.g. by measuring the sludge deposit in each channel by means of the observation tubes passing through the horizontal trays in the basin, and by adjusting the inlets and outlets until the distribution is adequate.

It always seems to be possible to eliminate kinetic currents to a sufficient degree by utilizing suitable inlet and outlet arrangements, but this aspect of the problem seems to be ignored in too many cases. It is better to use a comparatively large portion of a basin for these devices, and obtain a good efficiency in a reduced sedimentation basin, than to impair the sedimentation efficiency in a larger basin.

The distribution of the water to be settled is equally important in the different settling basins. It is to be remembered that in most cases the settling efficiency drops fairly quickly at increased load, but gains very little at decreased load, and since the overloaded basins take most of the water, the total

settling might be greatly impaired by uneven distribution to the different units. Even if measuring devices are used on each settling basin it is recommended that inlet pipe arrangements should be made hydraulically correct to obtain the right quantity at different loads.

e) **Examples**

In the foregoing it is recommended from theoretical considerations that the first step, after choosing the overflow rate, is to calculate a sedimentation plant with respect to its hydraulic properties required to meet the local conditions. The final step would be to control and adjust it to other factors influencing the sedimentation and sludge dewatering.

It is not necessary to give the basin an extreme shape. The theories permit interior arrangements, so that most shape requirements regarding rectangular basins may be met. It is also possible to reconstruct old basins and increase their capacity considerably.

Along with the above reasoning studies have been made on a large number of basins of old and modern types, and basins before and after reconstruction. Full scale basins have been provided with glasswindows and sub-surface illumination and the flow observed. The difference in performance between the old types—mostly based on an overflow rate, a conventional depth and rate length to width—and the newer basins is quite striking. Unfortunately, it is very difficult in making a comparison between results obtained from different basins to separate the influence of only one certain factor. If Reynolds number is lowered by means of a number of longitudinal walls in a sedimentation compartment, the Froude number is raised. To construct basins exclusively for studying a certain factor is very expensive, and the sedimentation investigations take a considerable time. It has not been possible to carry out such tests. But the present experience from new and reconstructed basins, together with known facts from fluid mechanics, support the suggested method enough principally, although more investigations under different circumstances are highly desirable.

Examples are given below of the sedimentation properties of some basins when settling very light humus floc. The example show that a higher Froude number gives a more reliable sedimentation and that parallel operation, under these circumstances, is superior to series operation of a number of compartments. One example shows the value of hydraulic adjustment of inlet and outlet. The sludge problem, which is introduced in the discussion of the result, will be discussed more completely in a later section.

Example I. Water Purification Basin for a Sulphate Mill

The two old basins were built in 1935. Each basin was 105 ft. in length, 26 ft. in width, and 17 ft. in depth, and had a horizontal surface area of 2 700 sq. ft. Inlet perforated baffles were fitted at the inlet, and a weir was provided at the outlet. The raw water is soft and highly coloured. It required a coagulation dose of 80 - 90 p.p.m. alum (about 5 gr./gall.). The flow was very unstable. Reverse flow on the surface occurred regularly in the autumn. On some occasions the sedimentation effect dropped to zero.

The basins were reconstructed in 1947, and were provided with 2 wooden trays at a very small cost. The old flocculation basin had a theoretical detention time of 45 min. In order not to reduce the flocculation time when increasing the load, it was decided to use 1/3 of the sedimentation basin for flocculation. Each of the two lower compartments and the upper compartment were equipped with two longitudinal walls, thus affording 9 "channels." The wetted

perimeter was increased about 4 times and the effective sedimentation area from 5 600 to 11 800 sq. ft. At the requisite increase in load of 70 per cent, the filter runs are now approximately 60 per cent longer than before. No reverse flow occurs, and the efficiency is always good. The improvement in results is due to many factors. The detention time was 6 hrs. before, and is 2.4 hrs. after reconstruction. The overflow rate was lowered from 498 to 408 gal./sq.ft./dy., which will give a better possible effect, the Reynolds number was lowered from 1 500 to 1 100 and the Froude number was raised 10 times to $0.7 \cdot 10^{-6}$. In spite of the lower overflow rate sufficient stability was secured in the reconstructed basin. Similar results have been obtained elsewhere as in the town of Kramfors, Sweden.

At Kramfors the old plant, built 1937, had two sedimentation basins, length to width 1:4 and depth 12 ft., good inlet through baffled slots, and a coarse net and outlet over the weir. The plant was enlarged in 1953 with one new "block" consisting of a longitudinal flocculation basin and a 2-story sedimentation basin. The old basins were reconstructed to a similar block. Longitudinal walls were used to lower the Reynolds number. Comparison between the monthly average for October 1954 in relation to monthly averages in the years 1938, 1940 (first enlargement), 1942 (full hourly load) is given in per cent in table 1:

Oct. in the year	Load, hourly	Basin area	Overflow rate	Filter rate	Filter run per unit loss of head	Filter run total
54/38	270	210	128	140	200	190
54/40	270	210	128	180	85	102
54/42	168	210	80	110	133	270

The total filter run is determined from measurements of the purity of the filter effluent. The loss of wash water to clean the basins is now slightly less than 0.75 per cent as against 0.4 - 0.6 per cent for the years 1938 - 1942, at an increase in the total monthly output of 260 - 335 per cent. The water comes from a lake system and has a fairly constant analysis, but there are slight variations in the dosing. Tests indicate that a moderate variation in the dose will not influence the filter run, apparently because an increased dose gives a better sedimentation efficiency.

Example II. Water Purification Settling Basin for a Sulphate Mill

A pre-determined situation necessitated a relatively short basin. In view of the good results obtained in basins with one tray and two compartments in series, built during the period from 1930 to 1940, it was decided to choose this type of basin, but to try three compartments in series. Outlet through skimmers of perforated false bottoms from each compartment was also tried. The water was extremely soft and highly coloured (about 100 p.p.m.), the coagulation dose was 70 - 100 p.p.m. Alum (4 - 6 gr./gall.), and the load was 3 - 4 m.g.d. on a total effective surface area of 4,000 sq. ft. The theoretical detention time was less than 1.7 hrs. The sedimentation was fairly good at the lower load, but, owing to the voluminous floc, the first compartment was filled with sludge in one week, and then erosion took place. The second and the third compartments were unable to settle out much of the remaining sediment at the increased overflow rate. After developing the theories discussed herein, the basin was converted into a three-storey parallel-operated basin

in 1948. The curves showing the Reynolds and Froude numbers before and after reconstruction (using different numbers of longitudinal walls) are reproduced in Fig. 11.

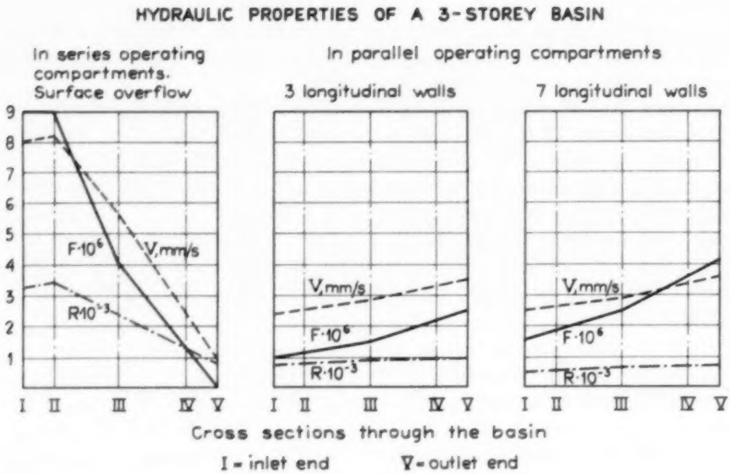

Fig. 11

Use was made of three longitudinal walls (12 "channels"). The outlet consisted of slots in the upper parts of the compartments. The runs were increased by 300 per cent to 3 weeks. The sedimentation efficiency was improved (longer filter runs), and the sludge was distributed on the bottoms of all the sedimentation compartments, and not only in the first compartments. The result obtained in this case was influenced by so many factors that it was not possible to draw too definite conclusions. The parallel operation was no doubt the most important of these factors, but the longitudinal walls, which resulted in a low Reynolds number and in an increasing Froude number that was not too low in spite of parallel operation, also seemed to be important. It is to be noted that the Reynolds number is about 900. The Froude number is $2 - 4 \cdot 10^{-6}$. It is relatively low, but perhaps sufficient in this case, where the differences in specific gravity are very slight. It is of special interest to notice that the higher Froude number, which favours stabilization, and the two turbulent zones in the series-operated basins, which favour coagulation and agglomeration, seem to be much less important than the good hydraulic conditions in the straight flow parallel-operated basin.

Example III. Water Purification Basin for a Steam Power Plant

This basin was built in 1943. It was comparatively long, and had 2 compartments operated in series. The lower compartment was used as a primary

settling compartment. In order to increase the capacity, it was decided to reconstruct the basin in 1949, so as to convert it into a parallel-operated 3-story tank with longitudinal walls. The lower compartment was divided horizontally by one tray and vertically by two longitudinal walls. The upper compartment was provided with 4 longitudinal walls. The effective area was increased 50 per cent. At a 100 per cent increase in capacity, the filter runs were slightly longer than before. This case shows that the longitudinal walls and the parallel operation made it possible to increase the load by more than 100 per cent, but the sedimentation surface area was increased only 50 per cent.

Example IV. Recently Built 7 m.g.d. Water Purification Basin for a Paper Mill

This 4-storey basin with 12 channels is used for settling activated silica-aluminium sulphate-precipitated water. Since the basin was to be built in an old housing, it was very difficult to design good inlet and outlet devices. The trimming of the basin was therefore very desirable. The thickness and growth of the sludge layers were taken as a measure of the load carried by each sedimentation channel.

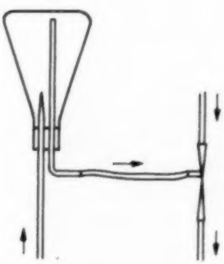

Fig. 12

The top of the sludge layer was determined by lowering a suction hose of very small diameter through the inspection tubes of the basin (27 tubes) and by sucking the liquid through a visible orifice in a glass bottle, Fig. 12. Now a simpler arrangement without the bottle is possible with the help of a clear plast-hose. Photo-electric cells may also be used. Fig. 13 shows the result at the point with the highest sludge level.

The first measurements, see curves a, indicated that practically no water flowed through the central sections, and that widely varying amounts of water flowed through the different lateral sections. An increase in the outlet velocity and loss of head gave a much better result, see curves b, and produced about 50 per cent longer runs. Some changes at the inlet end, e.g. the addition of double orifice baffles, shortened the inlet disturbing zone and slightly improved the sludge distribution. The distribution is not yet quite satisfactory, but trimming will be continued, and it is believed that it will improve the operating results. Since it is necessary to limit the water velocities in order not to break up the floc and not to impair filtration, trimming is very difficult. The kinetic energy generated in the primary inlet devices plays an important part in this connection.

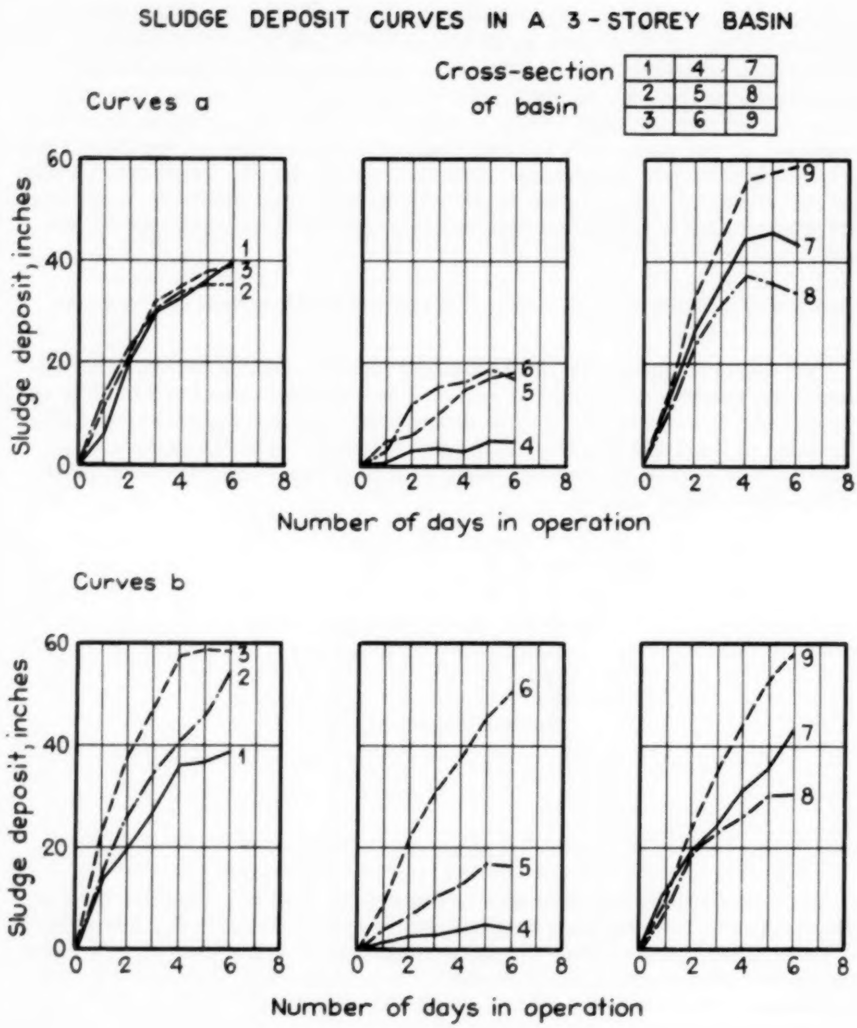

Fig. 13

Example V. Some New Basins

Several new multiple story basins have been built during the last years. Among them may be mentioned water purification basins at the towns of Norrköping (100,000 p, 3 stories), Linköping (60,000 p, 3 stories), Uddevalla (27,000 p, 3 stories), Vänersborg (15,000 p, 4 stories) and several wood pulp and rayon industries. The experience indicates that the total detention time in the mixing and sedimentation basins with the suggested design can be as short as in a precipitator, but the former type is much less sensitive to variations in load (flow, temperature and amount of sludge), and the water losses

with the sludge withdrawn will be much smaller. Straight flow sedimentation is not as sensitive as the precipitator in cases of errors in the dosing of chemicals. Very little of the sediment will be dissolved in that time when a complete dissolving may occur in the precipitator.

The Sludge Problem

Rapid Increase of Sludge Deposit in High-Rated Basins

If the load carried by a settling basin can be increased by reconstruction to a considerable degree, say to 5 - 10 times the rating of a plain basin (per volume), then the sludge deposit will increase something like 5 - 10 times as quickly as before, and if the sludge space is the same, it will be filled up in less than 1/5 - 1/10 of the previous time.

Solid particles, such as sand, form a dense sludge in a very short time. This kind of sludge does not give rise to any serious problems in a basin where the sedimentation conditions are good. The sludge may be removed at comparatively long intervals if some sludge space is provided, or may easily be removed by sludge removal mechanisms, which do not cause any excessive water losses. In this case a multiple tray basin with very low compartments may be used providing that a cheap and reliable cleaning system could be developed.

Flocculous matter as well as very fine particles, such as fine clay, form a more or less watery sludge. In a multiple story tank the height of the sludge layer, and hence the pressure on the bottom layer, is less than in a plain basin, but the surface area is as much larger, and the average water content, and hence also the sludge volume, are found to be less after the same detention time. The dewatering of sludge must be in direct proportion to the sludge area, but is also a function of the time. Since the detention time in the "high-rate" basin, e.g. a multiple-story-tank, is much shorter than in the old plain basin, the water content in the former is nevertheless much higher than in the latter. If the sludge is very light, the sludge space may be filled in such a short time that erosion will set in after only a few days. The shorter the runs, the higher the sludge water percentage, and this will obviously result in a "self-braking" effect. The water losses and the operation costs will be excessive. Such a basin can be said to be too good from a sedimentation point of view.

Sludge Deposit Characteristics

Under simplified conditions fig. 14 a and b shows some theoretical sludge curves in sedimentation basins with stabilized flow. In this figure are shown a straight flow basin and an analysis diagram indicating the percentage of a certain sediment with a certain settling velocity corresponding to a certain overflow rate.

In fig. 14 a, type I and II, sediment has only one grain size respectively with a settling velocity corresponding to 200 and 100 per cent of the overflow rate for the basin. The sludge deposits will be the rectangles AEFG and ABHK.

In fig. 14 b with a sediment curve indicated by III a, summary curve, or III b, mass curve, the sludge curve will be the line NML. From a given sediment analysis curve and basin it is always possible to get the theoretical sludge deposit curve of inert material as sand or grit.

The actual sludge curves from a watery sludge will depend upon the water

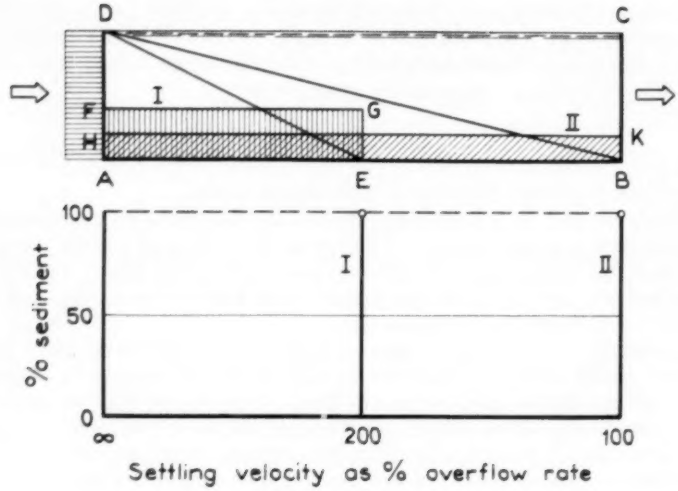

Fig. 14a

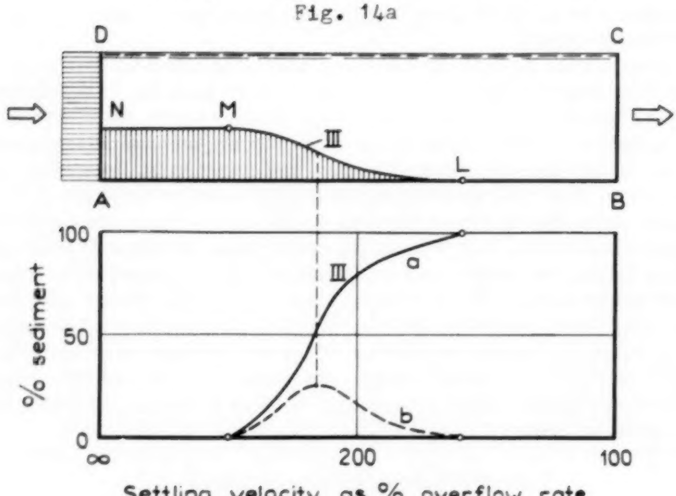

Fig. 14b

percentage of the sludge at the different points in the basin. Sludge level measurements in one of the 3 basins for water purification in the city of Linköping are shown in fig. 15 a.

Each basin is a 3-story parallel flow basin. The sludge curves in the different compartments follow each other very closely, fig. 15 b.

With the load and type of sediment present, the deposit is rapid in the first part of the basin, and the sludge level reduces the free settling zone to only 2 ft. in about one month, when scouring takes place at a velocity of about 1.5 in/sec. Continued operation of the basin decreases the settling efficiency, because the overflow rate increases and very little settling can take place in the first part of the basin. Furthermore the turbulence increases and the Froude number decreases in the rest of the basin, which may reduce its settling properties.

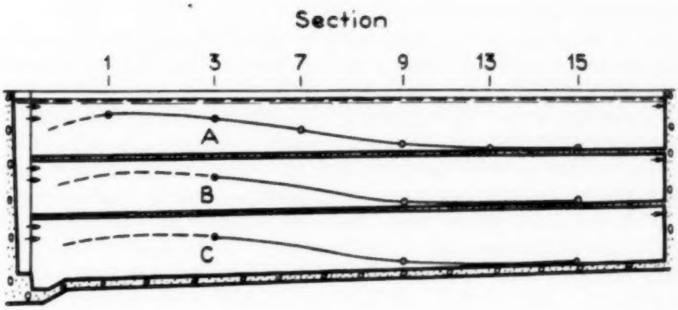

Fig. 15a

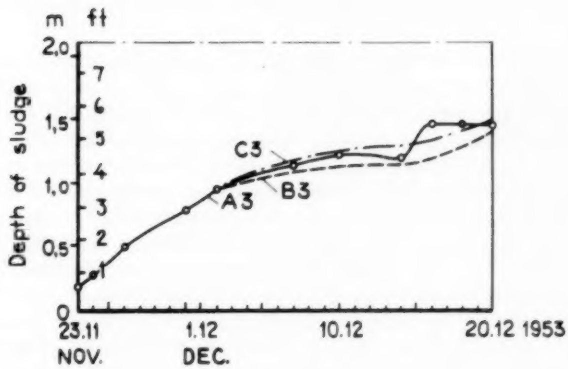

Fig. 15b

It is obvious from the above that compression or removal of the sludge under operation is highly desirable in high-rate sedimentation basins in order to maintain the best hydraulic conditions and the high settling efficiency. Such methods must also be studied with respect to economy and technical design.

Means to Keep the Desired Relation Between the Sedimentation and the Sludge Zone

In a full loaded sedimentation zone further diminishing of the space will reduce the efficiency. Also the sludge deposits, in most cases, will be irregular because of the character of the sediment, or the percentage of load. It is always necessary to allow some space for the sediment in a settling basin, even if means for a continuous or intermittent cleaning under operation are provided. Such cleaning with a small space may cause excessive losses of water. The question will then be how large a space is necessary from an economical or operational standpoint. In cases with very light watery sludge a relatively great part of the volume of the basin might be required for the sludge space. This will impair the sedimentation properties of the basin, but such a disadvantage must be taken.

a) Continuous Cleaning Devices

Sediment of solid particles, such as grit, sand or silt, which form a dense sludge, can be removed by scrapers and conveyors with no great losses of water. The sludge space can, therefore, be small and the basin be designed mainly as a settling zone. Horizontal (or sloping) trays can be used to any desired degree that is acceptable with respect to sludge cleaning facilities.

Flocculent matter as well as fine clay, fiber etc. which form a more or less watery sludge may be removed continuously or with relatively short intervals. With the more heavy types the sludge space can be limited to a still unimportant part of the settling-sludge volume. Very light sludge forms a very watery sludge. With continuous sludge removal the water loss will be great, with intermittent sludge removal the sludge space will be very great. This will probably give too large a settling zone at the start, and a narrow, irregular shaped zone just before cleaning.

Though the sludge problem is primarily technical as shown above, it is nevertheless finally a practical and economical one. The technical possibilities for cleaning, their operation costs and the evaluated water losses will have influence.

The problem of more or less continuous sludge withdrawal in aluminium sulphate precipitation, especially in fairly large multiple-storey basins has been investigated. The equipment may comprise of revolving, reciprocating, or endless sludge scrapers or suction devices, sectionalized draining pipe systems, hoppers (sloping baffles), or the like. The cost will vary with local conditions, viz., the type of foundation, the corrosiveness of the water, etc. It seems that the cost of construction of a basin designed for, say sludge storage for less than 1 - 2 days, with possibilities of sludge removal during operation will be higher than that of a basin designed for the shortest run of say one week.[12] The water losses in, and the operating costs of, the "continuous" cleaned basin will be much higher. The water losses will be, according to the type of water and the actual length of run, about 0.6 - 1.5 per cent in a basin with the shortest run of one week, against 3 - 10 per cent or even more in a basin with "continuous" sludge withdrawal. Accelerators for the same type of water will cause fairly high water losses in spite of the low load which is necessary (4 hrs. total volume). In conclusion, it can be stated that the "one-week" multiple storey basin seems, at present, to be the most economical for settling water forming a watery but non-putrefactive sludge. If a cheap and practical solution of an intermittent cleaning method during load is developed, it would still be preferable to use such a device than to empty the basin. If would also be possible to maintain the hydraulic properties of the basins in better condition. Tests are under way with reciprocating perforated pipes, and it does not seem impossible to "blow" the basin and to lengthen the run between cleanings by this mean.

Other reasons than the avoidance of high sludge water content also indicate the desirability of compartments which are not too low, or having too many stories in the same basin. In determining the height of each story in such a basin, it is necessary to take into account the accessibility to workers for trimming and repairs, the amount of wash water and the washing time, the possibility of distributing the (settling) water, etc. Difficulties will arise when the height is less than 5 - 6 feet. Adjustments must be made, especially

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12. This run has been chosen because, both in domestic and in industrial uses, it is generally possible to clean the basin during the periods of low consumption on Sundays.

when the basin is new and it is very difficult and time-wasting to work in a space that is too low or narrow.

Basins receiving a very light and watery sludge with a maximum capacity up to 8 m.g.d. and 3 - 4 stories have been found to be washed conveniently by using plenty of water, and then no appreciable pressure is necessary. Water is taken from the inflow channel (flocculated water; raw water may also be used, if pipes are provided), fed at the same time in sufficient and proportional amounts into each channel, and distributed over the entire width by means of weirs. The valves might be operated wholly automatically by a timer. By using this method, the whole basin can be cleaned in about 15 minutes, to which the emptying and filling time must be added. Too many stories might introduce complications. To feed the wash water over too many troughs will be difficult, and require too large amounts of wash water, or it will be necessary to divide the cleaning process into several operations, and to repeat each operation once or more. This will involve a loss of time, etc. Finally, the distribution of the flocculated water and the control of the amount of sludge on each tray will be difficult and tiresome. Of course this cleaning method cannot be used when a basin receives heavy sludge.

b) Compaction and Conditioning of Sludge

In those cases when a basin receives a very voluminous and light sludge and hence a great space of the basins volume must be reserved as sludge space with all the disadvantages this includes, every means to "compact" the sludge by special method must be carefully investigated.

Compaction of sludge has attracted interest as long as settling has been widely used. Heavying materials, various coagulants, and, in the last decade, "coagulating aids" have been tested. Experience shows that all heavying materials, such as clay, iron oxyde, silica, crushed iron ore, etc., are beneficial to settling and to the compacting of sludge. For instance, in the basin in Example II, the addition of only 0.5 gr./gal. of a certain clay was sufficient not only to stop the increase in the sludge layer but to compact a built-up layer about 0.3 ft. per day. But such materials increase the "clogging rate" of the filters and shorten the filter runs. Furthermore, fine particles, which can be highly objectionable in some industries, may be abundant in the purified water.

Dewatering of the sludge by means of vibration or centrifuging or similar means outside of the basin and returning the liquid to the basin may be mentioned.

When coagulation is used, ferric compounds can be advantageous, but they are generally less efficient in colour reduction than the "light" coagulant aluminium sulphate, and for most industrial purposes it cannot be used because of the risk of iron in the purified water. The most promising agents are coagulant aids. Baylis' and other researchers' investigations of the activated silica process is one of the most important improvements in coagulation and compaction. Silica and similar aids seem to offer possibilities of very great importance for most purification processes for consumption water.

Conditioning of the sediment is another mean of making it more suitable to the sedimentation process. Especially important is instant mixing with chemicals when used and prolonged mixing. Untreated waters can also be conditioned as is proved by stirring or preaeration of sewage.

Discussion of Design

Going out from conclusions of computations and experience presented,

implying that the fundamental conditions for the validity of the Hazen overflow rate theory can be fulfilled by intelligent utilization of the hydraulic factors determining stability, turbulence and inlet and outlet distribution, it is possible to deduce some types of sedimentation basins, whose differences are caused mainly by the type of liquid and sludge to be settled.

For settling of solid particles such as grit, sand, silt and dense floc, the multiple story basins with narrow space between the trays (horizontal or sloping) have great possibilities to be used to advantage. Fig. 16 shows a basin in principle.

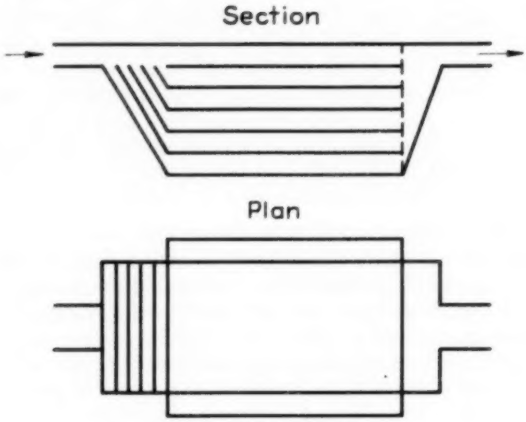

Fig. 16

Some solutions of the sludge cleaning system have been suggested and tested, and improved types will, no doubt, be available if this basin is more widely accepted.

For settling of flocculous matter with a fairly high water content the great advantages, in many cases, of tray settling basins cannot be overestimated. In this case each compartment of the basin must be given a sufficient height to accumulate the sludge for dewatering before removal intermittently. This type of basin is recommended for nearly all "cleanwater"-sedimentation purposes e.g. in connection with chemical pretreatment. Its adoption is in no way an experiment. The basin shown in fig. 17 has been used in several water purification plants with a very good result. The cleaning of the basin should be carried out at the longest possible intervals, either by flushing out or emptying and washing the floors. In certain cases sludge scrapers can be used.

In settling of putrefactive sludge, e.g. in sewage treatment, more or less continuous cleaning is necessary. For primary settling, only 1-story basins seem to be advisable. Such basins should be shallow, and their length-to-width ratio must perhaps be high to ensure good stability. It is quite possible to provide such a basin with vertical longitudinal walls if the sludge scrapers are not too wide, fig. 18. The walls can be located wholly below the water level to avoid "greaseshelves" on the walls.

For secondary settling, e.g. of activated sludge, investigations indicate that multiple story basins could be used with great advantage. Doubt has been expressed regarding disturbance from upfloating materials. Measurements have shown that the amount of "scum" is a very small percentage of the total

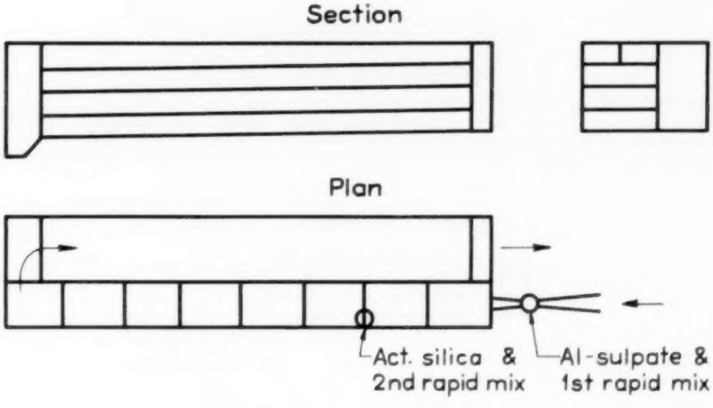

Fig. 17

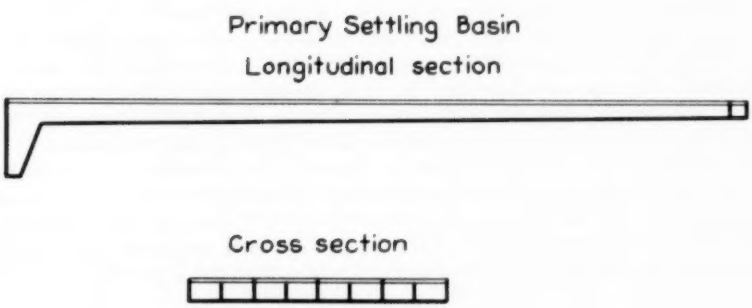

Fig. 18

amount of sludge. Most secondary basins have consequently no scum weirs, so there would be little difference in an open or a roofed settling compartment. Of course the scrapers must clean the roof and gas must have the possibility of escaping. There is still no operating experience from such basins, but some basins are under construction of the type shown in fig. 19, and in more detail in fig. 20.

The sludge will be withdrawn from the inlet end, and special precautions will be taken in order not to mix the sludge with the incoming water. The clear water from each compartment will be observed at the outlet, where scum can also be separated.

From the foregoing it will be evident that it should be possible to build the primary basin above a multiple story secondary basin. Fig. 21 shows a project with this design for a covered activated sludge treatment plant in rock.

It is desirable for these basins, when settling light sludge, to get simpler and lighter sludge scraping mechanism. It seems to be possible to avoid heavy chains and scrapers which are liable to excessive wear.

Cost analysis between conventional plants and plants of the above design are continuously made and indicate considerable savings with tray settling basins.

Secondary Settling Basin

Longitudinal section

Cross section

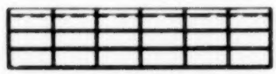

Fig. 19

The design of a sedimentation plant like most engineering objects is necessarily a compromise between theoretical and practical considerations. A theoretically correct design may require equipment that is not available, or perhaps will be expensive or unpractical to use. From an engineering point of view the right design is not always the most ingenious, but the most economical. Generally we advance towards the theoretical best design as the most economical one. In sedimentation basin design the advancement has been slow, perhaps because it is an old art with strong traditions.

The inexperienced designer must be careful when adopting the above types of basins. It is necessary to make sufficient investigations of the local circumstances. In the future more basins will nevertheless be designed with regard to the actual conditions as characteristics of the sediment and liquid, requirements of the basin a.s.o. and fewer after the "thumb-rule."

CONCLUSIONS

Practically all conventional basins with the same overflow rate can acquire the same maximum settling efficiency. Most conventional basins of any design with the same overflow rate have about the same average settling efficiencies. Very unstable basins, such as the conventional radial flow basin designed for taking care of waters causing certain density currents, e.g. activated sludge liquor, will show a fairly acceptable effect.

In this paper it is shown that, under very special conditions, a basin with irregular flow can give a better settling efficiency than a basin with undisturbed flow.

What will then be gained by basins with hydraulicly good properties?

Most basins with unstabilized flow will, now and then, show very great variations in the settling efficiency caused by kinetic and density currents, wind action a.s.o. They have a "dead" volume that is not necessary for their performance. To predict their efficiency is more or less a guess-work. They can never be designed for a top load, on the contrary a high safety factor is necessary when choosing the data.

From a logical reasoning the designing engineer has only one choice and that is to make efforts to get a basin with as undisturbed flow as possible. The only alternative would be to design the basin with full knowledge that the hydraulic properties are bad.

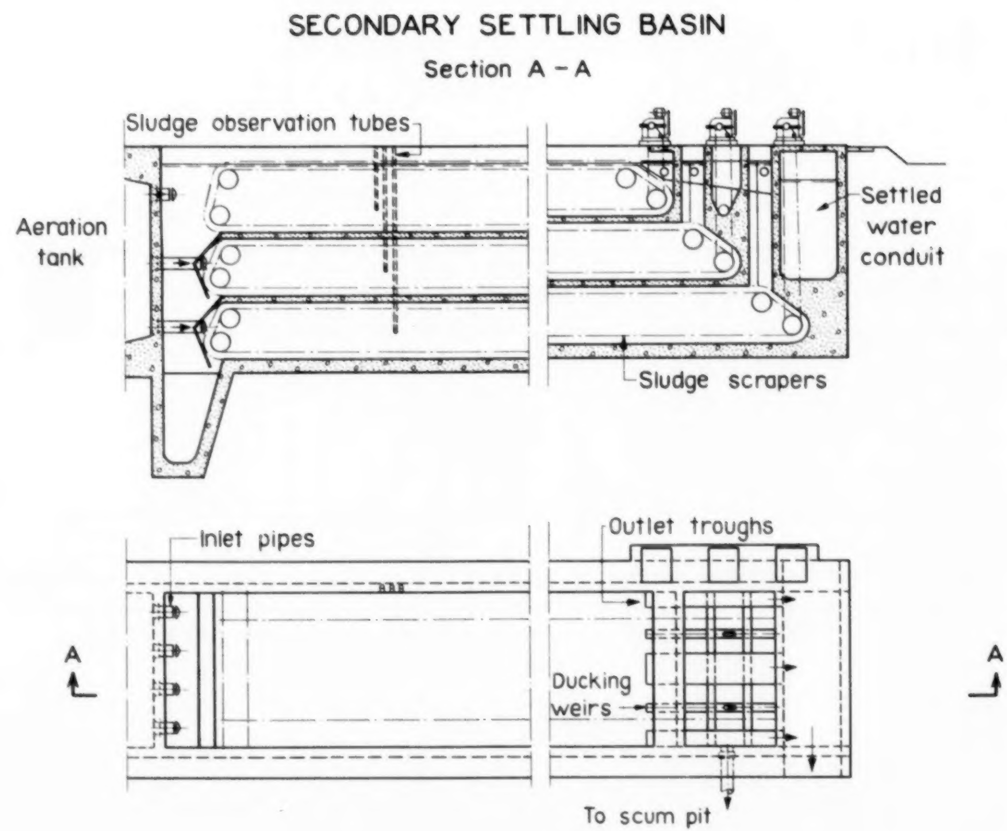
SECONDARY SETTLING BASIN
Section A - A
Sludge observation tubes
Aeration tank
Settled water conduit
Sludge scrapers
Inlet pipes
Outlet troughs
Ducking weirs
To scum pit
A
A

Fig. 20

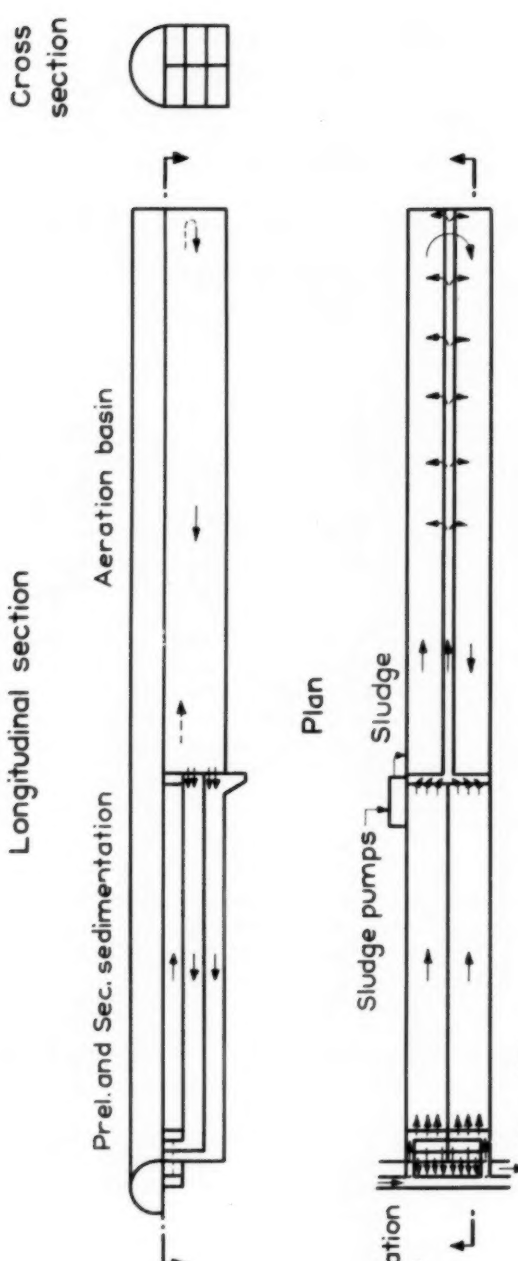
Longitudinal section
Cross section
Prel. and Sec. sedimentation
Aeration basin
Plan
Sludge
Sludge pumps
To outlet
From preaeration outside

Fig. 21

It is here recommended (1) to design the basins sedimentation compartments as parallel operated horizontal, straight flow channels with certain definite values on the Reynolds and Froude numbers, (2) to subdivide sufficient of the basin volume to obtain perfect inlet and outlet and (3) to divide the total flow equally on the different units. Means how to do this are suggested.

It may be mentioned that the fundamental principles can be applied also to the design of radial flow basins.

Going out from a basin with undisturbed flow it is possible from known properties of the sediment and known local conditions to choose the overflow rate and predict a result that will always prevail. It is possible to take full advantage of the overflow rate theory in designing the basin.

Some theoretical and practical aspects of the sludge problem under different conditions have been discussed.

Some examples proving the value of improved design have been presented, as well as some consistent types of basins.

The possibility to design basins with desired hydraulic properties and eliminate periods of low efficiency will result in very considerable saving in investment cost and space. More research and investigations regarding the necessary stability, the influence of turbulence and scour, methods for dewatering the sludge and cleaning the basins under operation etc. are highly desirable to give a firmer basis for the design.

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